# Homework #4

Due: October 15.

1. Design a lattice with four identical FODO cells. Let the basic cell consist of a thin lens, a dipole magnet, another thin lens and another dipole magnet. Pick suitable values for the two quadrupole strengths, drift length, and bending radius, so that there is stability in both dimensions.

   (a) What are the horizontal and vertical tunes?

   (b) Plot $\beta_x(s)$ and $\beta_y(s)$ and $\eta(s)$ for the periodic cell.

   (c) Calculate the momentum compaction.

2. CESR is an $e^+e^-$ storage ring at Cornell which operates at 5.3 GeV with 7 bunches of $e^+$ and 7 bunches of $e^-$ circulating in opposite directions. The approximate beam sizes at a collision point are $\sigma_x = 8.4 \times 10^{-4}$ m, $\sigma_y = 3.5 \times 10^{-5}$ m, and $\sigma_s = 2.2$ cm.

   (a) Assume that the circulating current per bunch is initially 8 mA, and the ring circumference is 768 m. What is the initial luminosity in one of the experiments?

   (b) Assume that the beam currents decay exponentially, with a lifetime of 2 hours. What is the integrated luminosity of one experiment for a 3 hour data taking run?

3. (a) The Superconducting Super Collider (SSC) died in the early 1990's in its construction phase, and has been laid to rest near Dallas. It was to have had head on collisions between 20 TeV proton bunches counter-rotating in two rings. What would be the required energy for protons in a fixed target accelerator that would produce the same center-of-mass collision energy?

   (b) The electron-proton collider HERA operates in Hamburg with two rings. One ring contains 30 GeV electron bunches, while the other contains 800 GeV proton bunches. What is the center-of-mass collision energy? What is the average momentum of the collisions in the laboratory frame?

4. Go to the PHY 684 home page and investigate particle motion under a computational model of the "standard map", very similar to the RF kicks used in an acccelerator for longitudinal focusing and acceleration:

   http://www.agsrhichome.bnl.gov/AP/Java/standard.html

   Clicking randomly on various points will launch particles through this map, demonstrating areas of regular contour-like motion and areas of chaos, with different values of $Q_s$ changing the balance between the two.

   (a) At what value of $Q_s$ does chaos start to dominate over regular motion? Print out a hardcopy of this phase space, and perhaps one or two others you find interesting, and include them with the homework.

   (b) Are there any values of $Q_s$ where stable motion completely disappears?